Environment Canada Environnement Canada

GREAT LAKES FACT SHEET

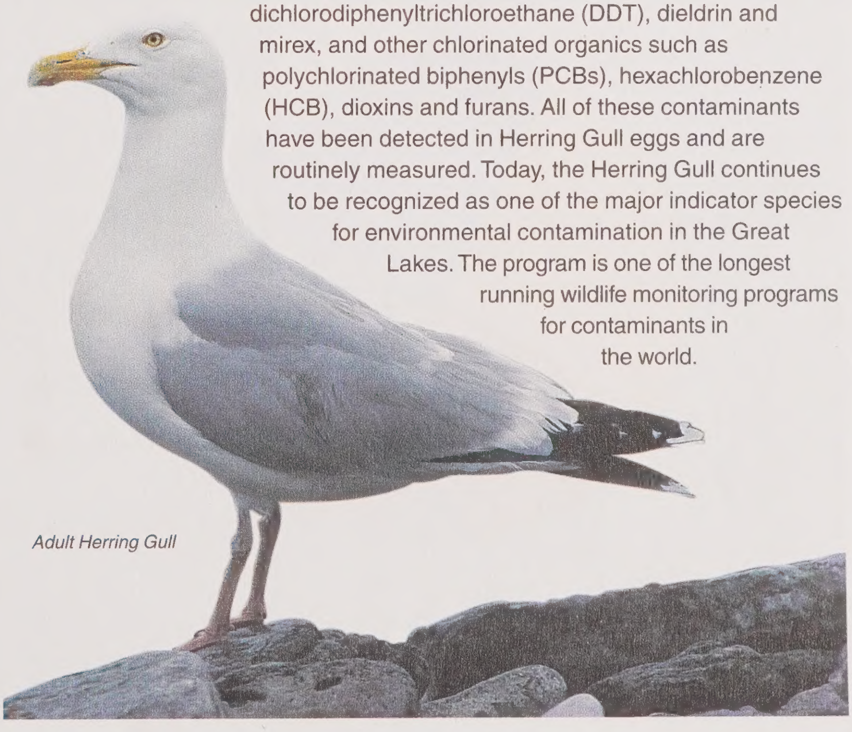
Contaminants in Herring Gull Eggs from the Great Lakes: **25 Years of Monitoring Levels and Effects**

This fact sheet describes changes in the concentrations of four selected organochlorine compounds found in Herring Gull eggs between 1971 and 1995. It also describes some of the biological effects associated with these chemicals which have been observed in both Herring Gulls and other fish-eating waterbirds living on the Great Lakes. Two of the compounds reported here originally entered the environment as organochlorine pesticides: dieldrin and dichlorodiphenyldichloroethylene (DDE), which is the stable breakdown product of the pesticide dichlorodiphenyltrichloroethane (DDT). The other two compounds discussed here are a polychlorinated biphenyl (PCB) and a dioxin known as 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). This fact sheet also explains the reasons for this ongoing monitoring program and how the results reflect the ongoing efforts being made to restore the Great Lakes ecosystem to a healthy state.

Introduction

In the early 1970s a biologist went to Scotch Bonnet Island along the north shore of Lake Ontario. He counted over 100 nests of Herring Gulls (Larus argentatus) on this small island. However he could find only 17 chicks; there should have been at least 100 (one chick per nest). Where were all the young? What had happened to them? At the same time, researchers were discovering that Herring Gulls and other waterbirds living in the Great Lakes, especially populations living in Lakes Ontario and Michigan, were among the most heavily contaminated in the world. It was these conditions that, in 1971, led the Canadian Wildlife Service (CWS) to establish a program to monitor persistent toxic chemicals in the eggs of Herring Gulls and to study the biological effects of these contaminants on waterbirds of the Great Lakes.

Over 400 different man-made chemicals have been detected in Great Lakes biota. Research and monitoring have focused on heavy metals such as mercury, organochlorine pesticides such as dichlorodiphenyltrichloroethane (DDT), dieldrin and mirex, and other chlorinated organics such as polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB), dioxins and furans. All of these contaminants have been detected in Herring Gull eggs and are routinely measured. Today, the Herring Gull continues to be recognized as one of the major indicator species for environmental contamination in the Great Lakes. The program is one of the longest running wildlife monitoring programs for contaminants in the world.



Adult Herring Gull

by Brian Morin

The Herring Gull

The Herring Gull is a large omnivorous waterbird, about 64 cm (2 feet) from bill to tail. Adult birds are white with light gray backs and wings; the wings have black tips with a white spot. Their bills are yellow with a red spot on the lower tip and their legs are pink.

The Herring Gull is the most widely distributed gull in the Northern Hemisphere. In North America, it breeds across the northern third of the continent, including all of Ontario, and is found on all five of the Great Lakes. In the early 1900s, Herring Gull populations were nearly extirpated due to earlier persecution at nesting sites and the demand for bird feathers from the millinery trade during the late 1800s. During that time, Herring Gull populations on the Great Lakes were at an all-time low. The Migratory Bird Convention of 1916 placed the Herring Gull under protection from further persecution allowing populations to expand both their range and breeding numbers. On the Great Lakes, Herring Gull populations began to increase in the 1940s.

Herring Gulls, being very social birds, prefer to nest in colonies, usually on small islands, but always near a body of water (lake, river, or the sea). This makes them very easy to locate and study. From the time Herring Gulls reach breeding age (at four years), they are year-round residents in the Great Lakes. Immature birds, however, do migrate away from the lakes in winter. Once established at a colony site, adult birds usually use the same nesting site year after year, many as long as 10 to 20 years.

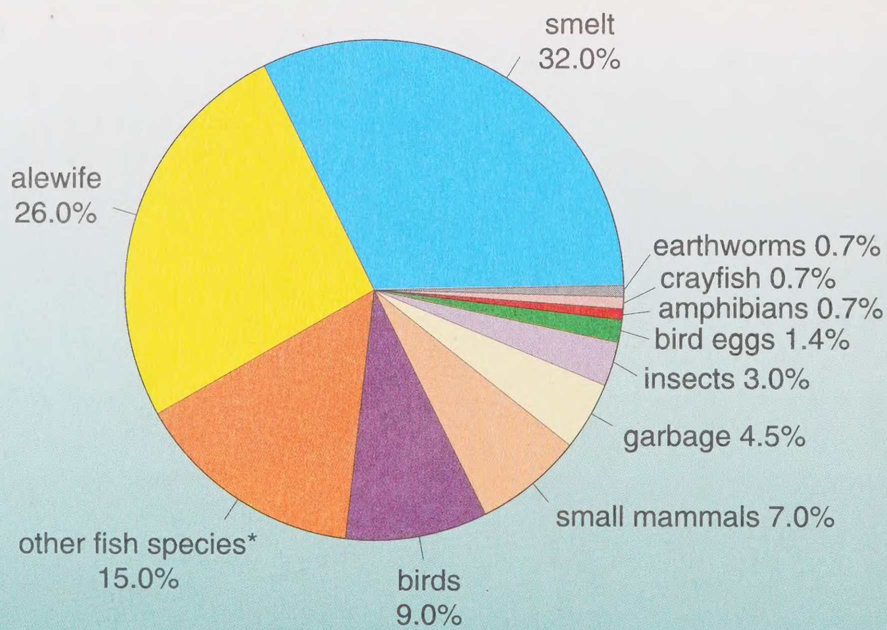
Adult Herring Gulls usually arrive at their breeding sites by early-March, and by early to mid-May females have laid their three eggs in a nest made of dead plant material (i.e. grasses, sticks and/or aquatic vegetation). Females will generally lay additional eggs to replace any that are lost early in the nesting season. Eggs are normally incubated for 26 to 28 days. After hatching, the Herring Gull chick will instinctively peck at its parent's bill, particularly at the red spot. This pecking stimulates the parent to regurgitate food for the chick. After about six weeks young birds begin to fly, but may continue to be fed by their parents for several more weeks. Mortality among Herring Gull chicks, which is mainly caused by food shortages and predation (usually by neighbouring gulls), is normally quite high. On average, only between one and two chicks per nest will survive to leave the colony.

Herring Gulls are opportunistic feeders. Examination of stomach contents shows that they will eat almost anything. Their diet consists of fish, small mammals, birds and their eggs, amphibians, earthworms, insects, crayfish, molluscs, vegetation and garbage. Fish, especially alewife and rainbow smelt, are particularly important food items for Herring Gulls on the Great Lakes (*Figure 1*).

by Pierre Mineau

Newly hatched Herring Gull chicks.

Figure 1. Diet compostion of Herring Gulls



* Other fish species include pumpkinseed, bluegill and rockbass.

Contaminants and the Great Lakes Food Web

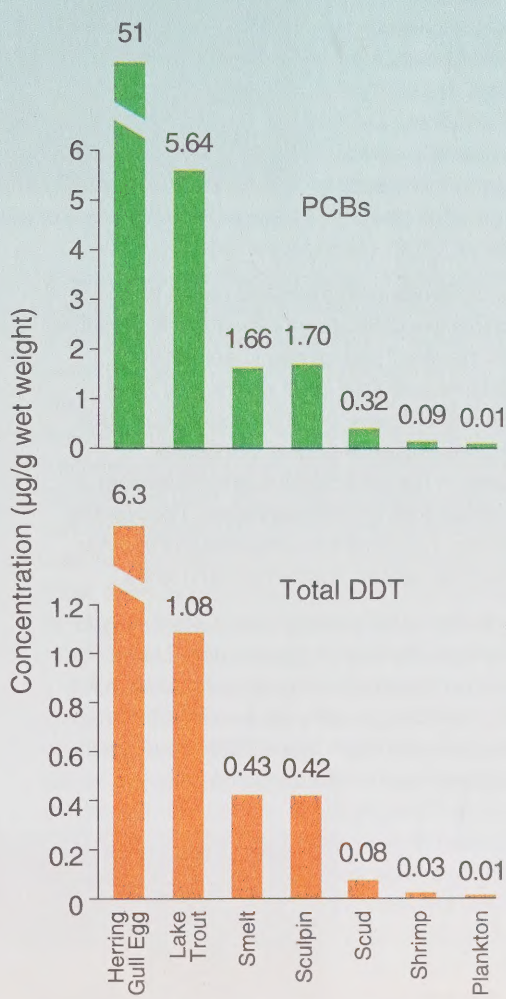
Modern industrial and agricultural practices in the Great Lakes basin began in the early 1940s. Since that time, thousands of chemicals and synthetic compounds have been discharged into the environment. Many of these are toxic, bioaccumulative and persistent. For example, organochlorine compounds such as dieldrin, DDT and dioxin resist bacterial and chemical breakdown processes in the environment. When they are applied as pesticides or are otherwise released into the environment (e.g. industrial effluents), they do not generally break down into harmless compounds as many less persistent synthetic chemicals do. Instead, they retain their chemical structure and, because they are not very soluble in water, they may evaporate into the air or attach themselves to soil particles. As vapor or on dust particles, the chemicals may be carried great distances and re-deposited by rain, snow and particulate fall-out onto land and water surfaces.

Within the water column, these toxic substances tend to be absorbed into the lipids of small organisms called plankton, thereby entering the lowest trophic level. As larger organisms eat the smaller organisms, contaminants move through the food web. This steady increase of contaminant concentrations in animal tissues from one tropic level to the next is known as biomagnification. Fish-eating birds such as Herring Gulls, Osprey's, Bald Eagles, Caspian and Common Terns and Double-crested Cormorants are top predators in the Great Lakes ecosystem and their diets consist almost entirely of fish and other components of the Great Lakes food chain. These species also accumulate the highest concentrations of toxic chemicals such as PCBs and DDE.

Biomagnification

Biomagnification has been demonstrated in studies that measured PCBs and DDT in different animals in the food web. In *Figure 2*, the animals living closest to or in the lake sediments, are on the bottom right-hand side of the graph. Plankton, crustaceans (such as freshwater shrimp) and amphipods (such as the freshwater scud) obtain nutrients and contaminants from suspended particles and represent one of the lowest tiers of the Great Lakes food web; they also have the lowest contaminant concentrations. These small organisms may then be consumed by fish, such as sculpin, which live near the bottom of the lake, or smelt. Eventually these fish are eaten by larger predators such as Lake Trout or gulls. At each step of the food web, contaminant levels are multiplied. Gulls tend to accumulate higher concentrations of contaminants than Lake Trout because gulls, unlike trout, are warm-blooded animals and require more food to maintain their body temperature. The more food eaten, the more contaminants a gull will absorb.

Figure 2. Biomagnification in the food chain in Lake Ontario



The Herring Gull as an Indicator of **Contamination and Associated Effects**

An animal or plant that accumulates contaminants from the area in which it lives can be used as an "indicator" of environmental contamination. Some of the characteristics which make the Herring Gull a particularly useful indicator of contamination of the Great Lakes ecosystem are:

by John Mitchell

Collecting Herring Gull eggs for contaminant analysis.

- There is already a lot known about the biology of the Herring Gull and the effects of environmental contamination on their breeding biology, metabolism and physiology.
- Herring Gulls are permanent residents on the Great Lakes, displaying little lake to lake movement in the breeding season. Other waterbirds of the Great Lakes such as Ospreys, terns, cormorants, herons, and Ring-billed Gulls, migrate annually and may be exposed to contaminants from their wintering grounds away from the Great Lakes.
- The Herring Gull is a top predator in the Great Lakes food chain. Contaminants that are difficult and expensive to measure in water or in animals that feed only on plants are easily measured in Herring Gulls and their eggs where they have biomagnified to much higher levels. For this reason, gull eggs can be used to detect the presence of new, previously unknown, contaminants in the environment, and increasing or decreasing levels of more common contaminants. The Herring Gull can also be used as a sentinel for contamination in other waterbird species, such as eagles, cormorants and terns.
- The colonial nesting habits of the Herring Gull make it easy to locate and sample its eggs. By using eggs it is possible to measure concentrations of contaminants without having to kill adult or young birds. Only 13 eggs per year are collected from each colony site (one per nest) since there is little variation in contaminant levels among eggs within the same colony.
- The Herring Gull is a common species and widely distributed, breeding on all five Great Lakes and in other regions of Canada and the world. This distribution allows direct comparisons of contaminant levels to be made in the Great Lakes basin as well as with other sites in and outside of Canada.

One of the drawbacks to using the Herring Gull as an indicator of the effects of contamination in the Great Lakes is that it is not as sensitive to organochlorine compounds as some other fish-eating waterbird species such as Bald Eagles, Common and Caspian Terns, and Double-crested Cormorants. For this reason these other species are often studied to supplement the indicator research documented on the Herring Gull.

In addition, Herring Gulls are not good indicators of point source contamination. Their large feeding range (up to 40 km from their colony) makes this species best suited as an indicator of regional contamination. For example, pollutant levels found in Herring Gull eggs at Hamilton Harbour will represent contamination in the western basin of Lake Ontario, not just Hamilton Harbour.

by Chip Weseloh

Herring Gull colony.

by John Struger

Herring Gull nest with eggs.

Selected Contaminants

DDE

Dichlorodiphenyldichloroethylene (DDE) is a "metabolite" (or breakdown product) of a synthetic pesticide known as dichlorodiphenyltrichloroethane (DDT). DDT was first introduced for widespread use as an insecticide just after World War II. Most uses of DDT were banned in Canada in 1969 under the Pest Control Products Act. Three years later they were banned in the United States. However, the use and the sale of existing stocks of DDT products were allowed until the end of 1990. Unfortunately, DDT is still used in many parts of the world (especially in developing countries) mainly for tsetse fly control and to help prevent insect damage to crops. According to figures from the World Health Organization, Mexico and Brazil each used almost 1,000 tons of DDT in 1992.

DDE, the most persistent of all the DDT metabolites, is routinely detected or encountered instead of DDT. DDE is produced in most animals when the body attempts to metabolize or digest DDT. DDE is also highly fat soluble. For these reasons, top predators, such as Herring Gulls, are more likely exposed to DDE than DDT from the food they consume. Very little DDT has been found in Great Lakes Herring Gull eggs, except during periods of high use of this pesticide in the early 1970s.

Dieldrin

Dieldrin has been in use in parts of the world since 1948 as a soil insecticide and seed dressing to kill fire ants, grubs, wireworms, root maggots and corn rootworms. Dieldrin is no longer imported or manufactured in Canada. Dieldrin is also the breakdown product of another widely used pesticide called aldrin, which has also been banned. In 1993, only one company in Ontario (and in Canada) had remaining stocks of aldrin and dieldrin. The last stocks have since been disposed of at a secured landfill site and dieldrin is no longer in use across Ontario.

PCBs

Polychlorinated biphenyls (PCBs) have been in use since 1929. There are 209 possible types of PCBs, referred to as congeners, which differ slightly from each other in their chemical and physical properties. A small number of these congeners are highly toxic and are thought to account for the bulk of PCB-induced toxicity in animals. PCBs, like DDT and dieldrin, are organochlorine compounds which persist for a long time once released into the environment. However, unlike the pesticides DDT and dieldrin, PCBs were not deliberately released into the environment. PCBs are extremely stable molecules, which make them desirable for industrial uses. Their low flammability made them useful as lubricants and as fire retardants in insulating and heat-exchanging fluids used in electrical transformers and capacitors. They have also been used as plasticizers, waterproofing agents, and in inking processes used to produce carbonless copy paper. Since 1977, regulations have been in place in Canada and the United States to ban the import and manufacture of PCBs, and tight restrictions are in place for the storage and destruction of all PCB wastes. One of the targets established in the 1994 Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA) calls for a 90 per cent decommission of high-level PCBs (greater than 10,000 ppm) in Ontario, destruction of 50 per cent of high-level PCBs now in storage and accelerated destruction of stored low-level PCB waste. All of this is to be achieved by the year 2000. Under the Commission for Environmental Cooperation, the United States and Mexico are presently developing a Regional Action Plan for the sound management of PCBs in North America.

2,3,7,8 -TCDD

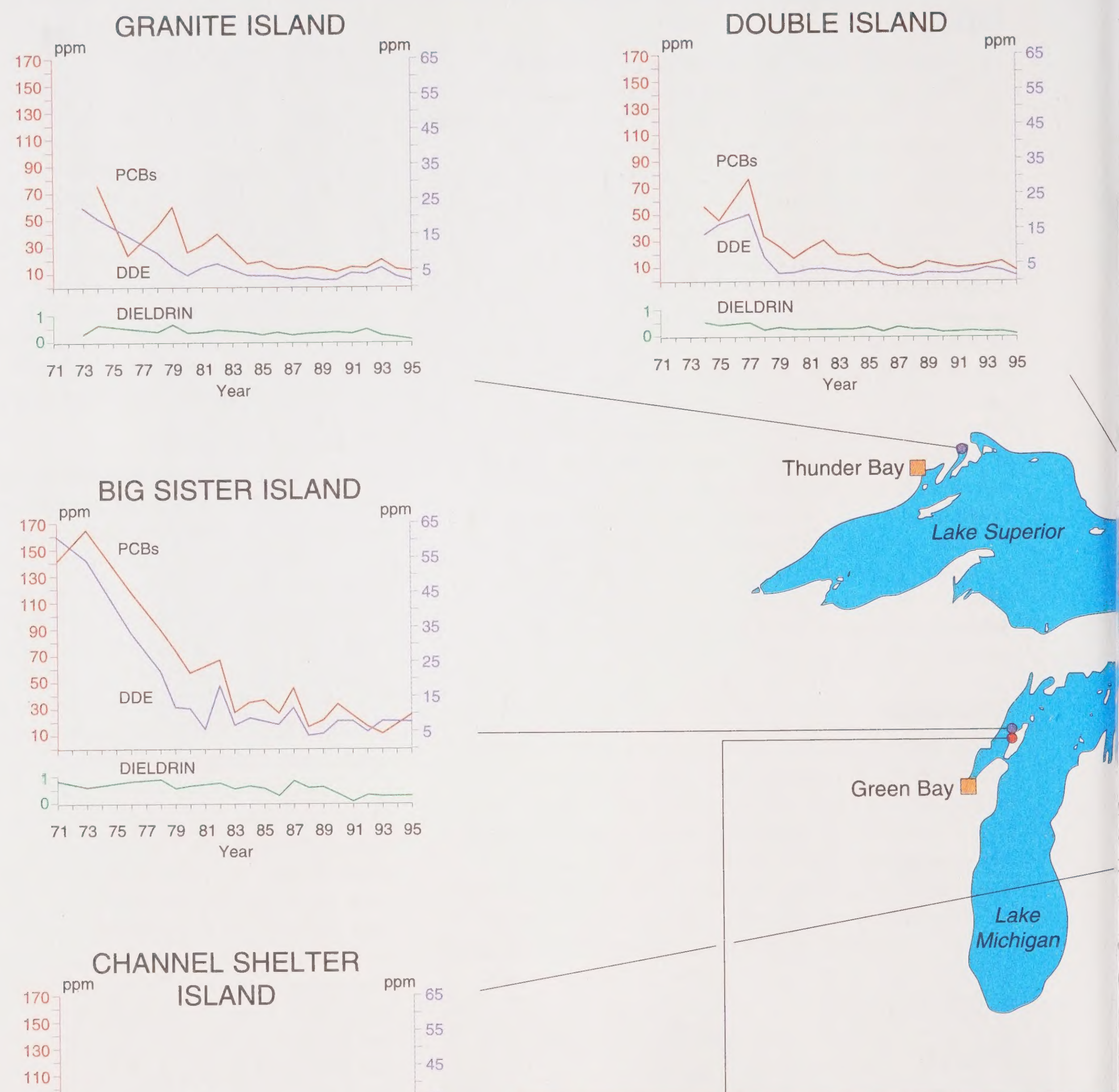
Dioxin is the popular name for a class of chlorinated hydrocarbon compounds known as polychlorinated dibenzo-p-dioxins (PCDDs). PCDDs and polychlorinated dibenzofurans (PCDFs) are formed either as by-products during some types of chemical production that involve chlorine and high temperatures, or during combustion where a source of chlorine is present. Only a few of the 75 different PCDDs and the 135 different PCDFs are highly toxic; others are practically harmless. The most toxic dioxin is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), although sensitivity to this compound varies considerably among animal species.

The most serious sources of 2,3,7,8-TCDD in the lower Great Lakes have been linked to industrial effluents and waste dump sites near the Niagara River and Saginaw Bay (Lake Huron). The former Hooker Chemical Company (now Occidental Chemical Company) in Niagara Falls, New York, produced 2,4,5-trichlorophenol (of which 2,3,7,8-TCDD is a by-product). Dow Chemical Company was identified as the primary source of PCDDs and PCDFs on the Tittabawasee River, which flows into the Saginaw River and eventually into the Saginaw Bay. Toxic waste disposal sites associated with this manufacturing, such as Love Canal along the Niagara River, have also been identified as important sources. The factories near Saginaw Bay and Niagara Falls discontinued the production of these chemicals in the mid-1970s.

Atmospheric deposition is also a major source of 2,3,7,8-TCDD, especially in the upper Great Lakes. The sources of atmospheric PCDDs and PCDFs include urban areas where municipal incinerators burn a wide range of chlorinated compounds put out with the trash, and from engine exhaust when diesel fuel is used. In the past, the use of leaded gasoline in vehicles was also a significant source of chlorinated compounds. The federal government phased out the use of leaded gasoline in Canada in 1990. A 90 per cent reduction in the generation or release of dioxins and furans by the year 2000 is targeted under the COA objective to "prevent and control pollution".

Monitoring Chemical Concentrations

Figure 3. Trends in average concentrations of PCBs, DDE and dieldrin in Herring Gull eggs at



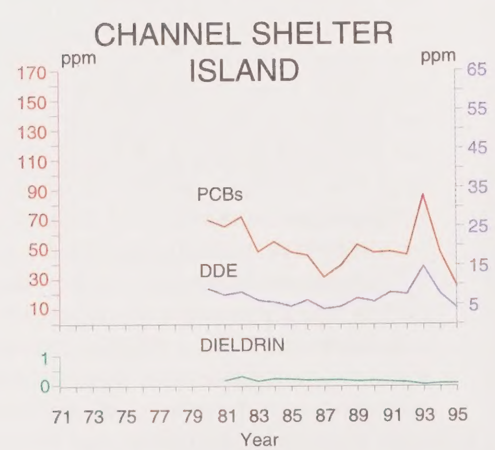
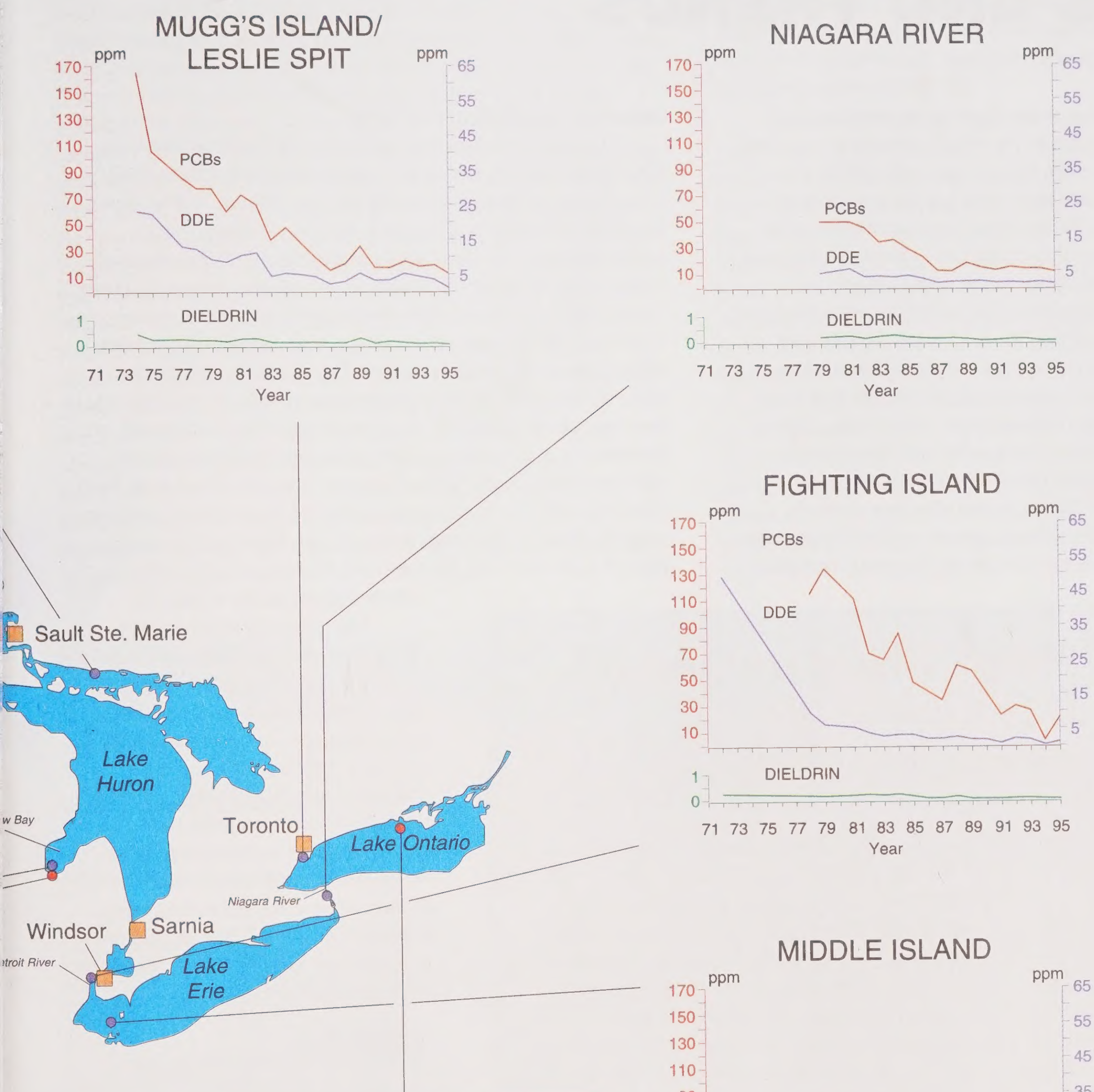
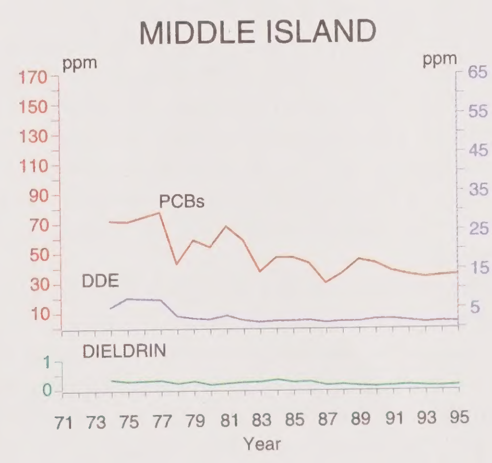
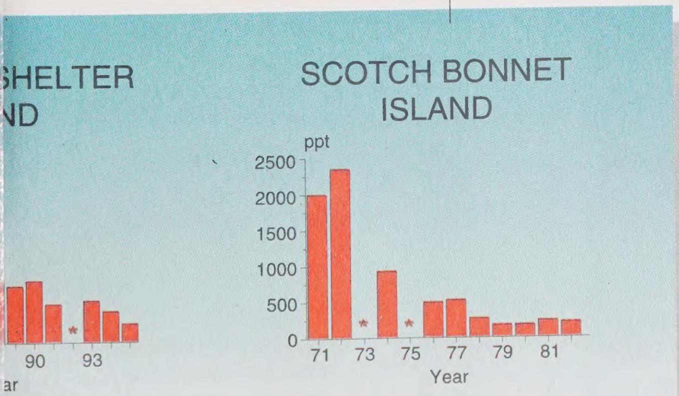


Figure 4. Trends in average concentrations of
Gull eggs at three colonies on the Great Lake

ght colonies on the Great Lakes (wet weight).







7,8-TCDD in Herring
et weight).

* - Indicates no data

Contaminants In Great Lakes Herring Gull Eggs — **LEVELS AND TRENDS**

1970s

Twenty-five years of monitoring contaminant levels in the eggs of Great Lakes Herring Gulls have shown that concentrations were highest in the early and mid-1970s and that levels from all sites have decreased greatly since that time *(Figure 3)*. However, it is almost certain that even higher levels of organochlorine contamination occurred in Herring Gull eggs in the 1960s, prior to the start of this monitoring program.

In the 1970s, the highest PCB and DDE levels were found in Herring Gull eggs from Lake Ontario, Lake Michigan and the Detroit River (although not all colonies in all lakes were sampled during this period). Lake Michigan Herring Gull eggs were also the most heavily contaminated with dieldrin. These higher levels of contamination were reflective of the intense agricultural practices, especially in fruit-growing areas in Lake Michigan and Lake Ontario, large urban populations, and large industrialized complexes present around these areas. However, these same sites also displayed the most dramatic declines in egg contaminant levels.

Herring Gull eggs from sites in Lake Superior and Lake Erie were generally the least contaminated with PCBs, DDE and dieldrin compared to the other lakes *(Figure 3)*. The lower contaminant levels in gull eggs from Lake Superior were probably due to the lower levels of development, industry and human population along its shores, in comparison with the lower Great Lakes. However, contaminant levels in Lake Superior eggs have not decreased as fast as levels found in eggs from other regions on the Great Lakes. This is mainly due to two factors. First, the amount of particulate matter in Lake Superior is very low. Since one of the ways organochlorine compounds are removed from the water column is through sedimentation of particulate matter, the rate of removal of these compounds from Lake Superior is slow. Second, unlike the lower Great Lakes, the major pathway for contamination of Lake Superior has always been the atmosphere. Atmospheric sources are difficult to control and are global in nature.

The generally rapid decline of most contaminant levels in Herring Gull eggs in the mid and late 1970s was mainly due to regulations that were implemented in the late 1960s and early 1970s, restricting the use and production of these persistent toxic chemicals *(see Selected Contaminants)*. In stark contrast to the declines observed in other organochlorine contaminants, levels of dieldrin in Herring Gull eggs from all areas on the Great Lakes remained relatively unchanged.

1980s

In the 1980s, the decrease in levels of some contaminants in Herring Gull eggs slowed and began to level off. This stabilization was largely due to different sources of contaminants compared with sources detected in the 1970s. Contaminant problems in the 1970s were due primarily to the production and disposal of chemical wastes. Most of these point sources have since been controlled. In the 1980s, primary inputs of persistent contaminants involved sources that were not as easy to control including: leaching from landfill sites via ground water, disturbance of contaminated

Year to Year Fluctuations — the influence of weather on contaminant levels in gull eggs.

The temporal trends portrayed in *Figure 3* mostly display a slow, gradual decline in contaminant levels in gull eggs since the mid-1980s with minor year to year fluctuations. Ongoing studies have shown that weather patterns in the late winter and early spring correlate very well with these minor fluctuations. Following a colder than average winter, contaminant levels in gull eggs are slightly elevated over what they would be in an average winter; following a warmer than average winter, the opposite occurs with slightly lower levels of contaminant levels found in eggs. The reason for this fluctuation seems to be that in colder than average winters there is a greater die-off of fish, e.g. alewives, which are rich in contaminants and then consumed by the gulls as food. This exposes the gulls to a higher than average contaminant load in their winter diet and the eggs they lay in the spring have slightly elevated contaminant levels.

Weather, and especially storm events, may play another role in the annual fluctuations of contaminant levels in gull eggs. Storms are known to cause turbulence to water currents and to cause disturbance or resuspension of bottom sediments. This can force contaminants found in the sediments, back into the water column. For example, a massive storm in the Saginaw River watershed in 1986 may have disturbed contaminated sediments, increasing the concentration of contaminants in the water column. This is thought to have led to increased 2,3,7,8-TCDD and PCB levels in Herring Gull eggs from Channel-Shelter Island in Saginaw Bay, in 1987. Elevated levels of these same compounds were also found in Caspian Tern eggs collected in 1987 from a Saginaw Bay colony and were associated with complete reproductive failure in that colony for that year.

lake sediments, and, atmospheric deposition.

Scientists detected 2,3,7,8-TCDD and other dioxins in Great Lakes Herring Gull eggs in 1980. These chemicals have been routinely measured since 1981. Pre-1980 dioxin levels were measured using eggs collected from Scotch Bonnet Island (Lake Ontario) and Big Sister Island (Lake Michigan) that had been stored at the Canadian Wildlife Service Tissue Bank. Levels of 2,3,7,8-TCDD in Herring Gull eggs from these two sites declined dramatically from the early 1970s *(Figure 4)*. In the early 1980s, two sites had particularly high levels of dioxins in Herring Gull eggs: Channel-Shelter Island in Saginaw Bay, Lake Huron and Scotch Bonnet Island in Lake Ontario. Elevated egg levels of 2,3,7,8-TCDD from these two sites were linked to effluents from past production of 2,4,5-trichlorophenol and 2,4,5-trichlorophenoxyacetic acid, and from the disposal of associated wastes at dump sites (see 2,3,7,8-TCDD in Selected Contaminants). In other areas of the Great Lakes, where levels of 2,3,7,8-TCDD were typically lower, the major source of this contaminant came from the atmosphere. However, since the mid-1980s dioxin levels in Herring Gull eggs from all areas on the Great Lakes have remained fairly constant with highest levels observed in eggs from Channel-Shelter Island in Saginaw Bay, Lake Huron.

1990s

Levels of some contaminants in Herring Gull eggs have remained relatively stable throughout the 1990s, with no significant changes observed in levels of PCBs and DDE at some Great Lake colonies. A few significant decreases in levels of dieldrin and heptachlor epoxide have been noted during this period *(Table 1)*.

This relative "steady state" in contaminant levels indicates that these chemicals are still being released and/or recycled through the Great Lakes ecosystem by individuals, households, municipalities, industry and/or agriculture. Atmospheric deposition, agricultural land run-off, the slow movement (leaching) of discarded stocks of pesticides and other chemicals from landfill sites and agricultural soils into the Great Lakes via groundwater, and the resuspension of contaminated lake/river sediments, continue to be major indirect sources of contamination. These indirect sources are difficult to control and contribute slow, but continual, contaminant inputs into the Great Lakes ecosystem. Atmospheric deposition has become an increasingly significant route of entry of contaminants into the Great Lakes ecosystem, especially in the upper Great Lakes. On Lake Superior, for example, up to 90 per cent of toxic contaminants entering this lake comes from the atmosphere in the form of precipitation.

Table 1. Trends in other organochlorine contaminants in Herring Gull eggs from eight colonies on the Great Lakes between 1990 and 1995

● = levels have remained relatively unchanged; ▼ = levels have decreased significantly.

There were no significant increases in contaminant levels during this period.

		Lake / River :	ONTARIO	NIAGARA	ERIE	DETROIT	HURON		MICHIGAN	SUPERIOR
Contaminant*	**Description**	**Colony :**	**Mugg's I.**	**Niagara R.**	**Middle I.**	**Fighting I.**	**Channel–Shelter I.**	**Double I.**	**Big Sister I.**	**Granite I.**
Dieldrin	insecticide		▼	●	●	●	●	●	●	●
HE	metabolite of an insecticide (B)		●	●	●	●	●	●	●	▼
HCB	fungicide, and by-product in industrial processes (B)		●	●	●	●	●	●	●	●
Mirex	organochlorine insecticide (N)		●	●	●	●	●	●	●	●
Photomirex	UV radiation degradation product of mirex		●	▼	●	●	●	●	●	●
Oxy-chlorane	organochlorine insecticide (B)		▼	●	●	●	●	●	●	●
QCB	industrial by-product		●	●	●	●	●	●	●	●
∝-HCH	components of lindane (an insecticide)		●	▼	▼	●	●	▼	●	▼
ß-HCH	currently used outside Canada		●	●	●	●	●	●	●	●
1,2,3,4-TCB	industrial by-product		●	●	●	●	●	▼	●	●
1,2,3,4-TCB TCB	industrial by-product		●	●	●	●	●	●	●	●

(B) = banned (N) = never used in Canada

* HE = heptachlor epoxide; HCB = hexachlorobenzene; QCB = pentachlorobenzene; ∝-HCH = alpha-hexachlorocyclohexane; ß-HCH = beta-hexachlorocyclohexane; 1,2,3,4-TCB = 1,2,3,4-tetrachlorobenzene; 1,2,3,5-/1,2,4,5-TCB = 1,2,3,5-/1,2,4,5-tetrachlorobenzene.

Effects of **Organochlorines**

The presence of elevated levels of toxic chemicals in the Great Lakes food chain has coincided with poor health, reproductive impairments and other physiological problems in Herring Gulls and at least seven other long-lived, fish-eating waterbird species, including Ring-billed Gulls, Double-crested Cormorants, Common, Caspian and Forster's Terns, Black-crowned Night-Herons and Bald Eagles. All of these waterbird species are top predators which feed, breed and live at least part of the year in the Great Lakes basin.

Problems such as reduced hatching success, eggshell thinning and abnormal adult behaviour during nesting were first detected in several of these species in the late 1960s and early 1970s. Since then other problems such as deformities in embryos and hatched young, biochemical changes, endocrine disruption and suppressed immune function have been observed *(Table 2)*. The majority of these effects have been most widespread when high levels of certain organochlorines have been found in both adult birds and their eggs. Eggs from these species become contaminated because the fat-soluble organochlorines are transferred from female birds into the fat that is required to produce the egg yolk.

Herring Gulls and other fish-eating waterbirds living on the Great Lakes have helped scientists, researchers and the general public understand the effects of prolonged exposure of bird populations to persistent toxic chemicals. Effects such as those described in Table 2 are often used as "biomarkers" when monitoring the health of wildlife in the Great Lakes. Biomarkers such as impaired reproductive function and biochemical or behavioural changes allow researchers to detect contaminant-related effects in individual animals at an early, preventive stage before they can lead to disability, disease and ultimately death at the population level.

Table 2. Summary of some contaminant-related effects observed in Herring Gulls and other fish-eating waterbirds inhabiting the Great Lakes

Contaminant Effect	Evidence in the Great Lakes	Current Status
Eggshell Thinning – caused by high DDE levels in the 1950s, 1960s and 1970s  by Chip Weseloh *Thin-shelled Herring Gull egg.*	– first confirmed reproductive problem related to contaminants found in birds on the Great Lakes – resulted in widespread eggshell breakage, causing population declines of fish-eating waterbird species including Double-crested Cormorants, Ospreys, Bald Eagles, Black-crowned Night-Herons and Herring Gulls	– due to regulatory controls and ban of DDT, eggshell thinning is no longer a problem resulting in improved reproductive success of affected species
Reproductive Failure – causes include early embryonic death, embryo toxicity and abnormal parental behaviour during incubation	– Herring Gulls, Double-crested Cormorants and Bald Eagles were not reproducing during the late 1960s and 1970s when highest levels of organochlorines were present	– due to significant declines in organochlorine levels, reproductive success has improved in most fish-eating waterbird species – Bald Eagles have returned to nest in many areas of the Great Lakes, except for the shorelines of Lake Ontario – the reproductive success of Bald Eagles is improving, but is not sufficient to maintain a stable population
Congenital Deformities  by Chip Weseloh *Double-crested Cormorant with a deformed bill.*	– most deformities reported in the early to mid-1970s from contaminated sites on Lake Ontario and in the 1980s on Lake Michigan – crossed bills, jaw defects, extra limbs, and malformed feet, joints and eyes were found in Herring Gulls and at least eight other species of fish-eating waterbirds	– waterbirds continue to display higher rates of deformities (e.g. bill defects in Bald Eagles) compared to clean sites outside of the Basin – greatest incidence in areas of high contamination such as Green Bay (Lake Michigan) and Saginaw Bay (Lake Huron) – studies continue on the links between contaminants and developmental problems in certain waterbird species
Biochemical Changes	– abnormal liver function in Herring Gulls including: increased activity of enzymes that attack toxic chemicals entering the body; elevated levels of porphyrins; and, unusually low levels of vitamin A – low levels of Vitamin A may increase susceptibility to infectious diseases, possibly affecting the survival and development of young chicks	– biochemical measures indicate that Herring Gulls are still chemically stressed – full effect of biochemical changes on the reproduction or life span of waterbirds is not known at this time

Contaminant Effect	Evidence in the Great Lakes	Current Status
Enlarged Thyroid – linked to exposure to certain contaminants (e.g. PCBs, DDE, dieldrin)	– most prevalent in Herring Gulls from contaminated sites including Saginaw Bay (Lake Huron), Green Bay (Lake Michigan), western Lake Erie and Lake Ontario	– in response to decreased contaminant levels in the Great Lakes aquatic food chain, the severity of enlarged thyroid has decreased in Herring Gull populations
Endocrine Disruption (feminization) – DDE is the most potent, abundant, persistent and bioaccumulative chemical that disrupts sex hormone function – sufficient exposure during early embryonic stages can result in abnormal development of male reproductive tissues and could reduce the number of normal males that return to the breeding colony – can result in supernormal clutches (nest with five or more eggs) as a result of two or more females occupying the same nest	– this effect was observed as early as the 1970s in Lake Ontario Herring Gulls when concentrations of DDE were high  by Pierre Mineau *Super normal clutch size.*	– the incidence and extent of endocrine disruption in Great Lakes Herring Gulls is currently unknown – research is underway to examine the relationship between chemicals that mimic hormones and effects observed in several waterbird species in the Great Lakes basin – a skewed sex ratio and supernormal clutches could also result from increased mortality of males – supernormal clutches are still being found on some Great Lakes Herring Gull colonies – very few of the eggs in a supernormal clutch are fertile and hatch
Suppressed Immune Function – several contaminants (e.g. PCBs and TCDDs) suppress important immune functions and can increase susceptibility to infectious diseases	– at highly contaminated sites Herring Gulls and Caspian Terns have suppressed T-lymphocyte function, atrophy of the thymus gland, and altered white blood cell counts	– recent studies indicate T-cell-mediated immunity in Herring Gull chicks suppressed by 35-45% in highly contaminated colonies in Hamilton Harbour (Lake Ontario), Saginaw Bay (Lake Huron) and western Lake Erie – research is underway to determine the extent and significance of this suppressed immune function in fish-eating waterbirds, as well as examine the relationships between immunological and other physiological effects
Genotoxicity – polycyclic aromatic hydrocarbons (PAHs) and some metals are capable of inducing genetic mutations	– DNA fingerprinting revealed higher mutation frequencies in young Herring Gulls inhabiting Hamilton Harbour compared to three rural sites (Kent Island in the Bay of Fundy, Chantry Island in Lake Huron and Presqu'ile Provincial Park in Lake Ontario)	– these mutations in DNA are thought to occur very early in development – such mutations may result in increased genetic disease or altered gene function leading to unfavourable changes in the gene pool

Improving the **Great Lakes Ecosystem**

The Canadian and the United States governments work together to improve the conditions in the Great Lakes through the binational Great Lakes Water Quality Agreement (GLWQA). Canada and Ontario have built a strong Canadian domestic program to achieve the goals called for under the Canada-U.S. GLWQA. In 1994, the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA) was established to assist in meeting Canada's obligations under the binational GLWQA. Both governments recognize that a cooperative partnership with the U.S. is vital to the long-term health of the Great Lakes Basin Ecosystem. This Agreement provides a process, commitments and guidelines for developing and implementing Remedial Action Plans (RAPs) for designated Areas of Concern (AOCs) and Lakewide Management Plans (LaMPs) for critical pollutants.

LaMPs are being developed to establish and implement chemical load reduction commitments under the binational GLWQA and to address the broader ecosystem issues common to both countries. There are binational LaMPs being developed for lakes Ontario, Erie and Superior. Individual LaMP programs are unique to each lake and are designed to restore targeted beneficial uses. Projects initiated by LaMPs have already produced promising results in improving water quality.

In conjunction with local communities, the private sector and all levels of government, Remedial Action Plans (RAPs) are also being developed and implemented in designated Great Lakes Areas of Concern (AOCs) identified by the International Joint Commission. There are 42 AOCs in the Great Lakes basin, including 17 in Canada (five of these are shared with the U.S.). The RAPs are working cooperatively to restore beneficial uses to these designated areas, most of which are located near large urban areas where pollution from industries, sewage treatment plants, landfills and other sources enters nearby rivers,

harbours and channels. Examples of beneficial uses include fish and wildlife habitat, beaches for swimming and drinkable water. One of four AOCs on Lake Huron, Collingwood Harbour, has been "delisted", making it the first AOC on the Great Lakes to achieve its restoration goals. An AOC is "delisted" or considered cleaned up when all beneficial uses which were lost through contamination and development are restored.

Research indicates that levels of persistent toxic chemicals in the Great Lakes have been substantially reduced over the past 25 years. Although this stands as a major achievement, there is still a long way to go to restoring the Great Lakes ecosystem to a healthy state. Current contaminant trends indicate a sustained contaminant load to the Great Lakes. Even though these contaminant levels are much lower than they were in the 1970s, levels of dioxins, PCBs and other related chemicals in the Great Lakes are still present due to undetected sources, atmospheric deposition and release from contaminated bottom sediments.

Fish-eating birds such as the Herring Gull continue to be good sentinels of aquatic food web contamination and associated biological abnormalities occurring in animals living in the Great Lakes basin. By monitoring contaminant levels in the eggs, researchers can detect the presence of biologically significant concentrations of chemicals in the Great Lakes that may, for example, interfere with the normal development of embryos or cause other subtle reproductive effects. These contaminants would be expected to occur in the tissues of any species, including humans, that eat large numbers of fish from the Great Lakes basin.

Obviously there are differences between birds and human beings, so the exact health effects found in the birds are not necessarily indicators of the same health impacts in humans. However, studies of infants of mothers who ate large amounts of highly contaminated Great Lakes fish indicate that some developmental effects can occur in the children. Assessment of potential effects of contaminants in human populations is usually based on the available information including the results of toxicological studies in other mammals, studies of highly exposed populations, and the degree of exposure. The effects of long term exposure to small concentrations of contaminants remains a focus of ongoing research in wildlife and human health.

The incidents of dead embryos in eggs, deformities and biochemical changes in birds in the Great Lakes should not be taken lightly. They are indicators of something amiss in the ecosystem and are linked to the emerging issue of chemicals and endocrine disruption. Other top-predator species in the Great Lakes have demonstrated similar responses, including humans. The Great Lakes must be clean enough for all species to live and reproduce normally. The challenge of restoring the Great Lakes ecosystem must be met in the future by the whole global community if virtual elimination of contaminants is to be achieved.

For Further Reading

Bishop, C. A., D. V. Weseloh, N. M. Burgess, J. Struger, R. J. Norstrom and K. A. Logan. 1992. An atlas of contaminants in eggs of fish-eating colonial birds of the Great Lakes (1970-1992), Technical Report Series, Canadian Wildlife Service, Ontario Region.

Colborn, T., D. Dumanoski, J. P. Myers. 1996. Our stolen future: are we threatening our fertility, intelligence and survival? : a scientific detective story. New York. 306 pp.

Ewins, P. J., D. V. Weseloh, J. H. Groom, R. Z. Dobos and P. Mineau. 1994. The diet of Herring Gulls (Larus argentatus) during winter and early spring on the lower Great Lakes. Hydrobiologia 279/280: 39-55.

Fox, G. A. 1993. What have biomarkers told us about the effects of contaminants on the health of fish-eating birds in the Great Lakes? The theory and a literature review. Journal of Great Lakes Research 19: 722-736.

Gilbertson, M., T. Kubiak, J. Ludwig and G. Fox. 1991. Great Lakes embryo mortality, edema, and deformities syndrome (GLEMEDS) in colonial fish-eating birds: similarity to chick-edema disease. Journal of Toxicology and Environmental Health 33:455-520.

Government of Canada. 1991. Toxic chemicals in the Great Lakes and associated effects. Vol. 1: Contaminant levels and trends and Vol. 2: Effects. Environment Canada, Department of Fisheries and Oceans, Health and Welfare Canada, Minister of Supply and Services, Ottawa. 755 pp.

Grasman, K. A., G. A. Fox, P. F. Scanlon, and J.P. Ludwig. 1996. Organochlorine — associated immunosuppression in prefledgling Caspian terns and herring gulls from the Great Lakes: An ecoepidemiological study. Environmental Health Perspectives 104 (Suppl. 4) :829-842.

Hebert, C. E., R. J. Norstrom, M. Simon, B. M. Braune, D. V. Weseloh and C. R. Macdonald. 1994. Temporal trends and sources of PCDDs and PCDFs in the Great Lakes: Herring Gull egg monitoring. 1981-1991. Environmental Science and Technology 28: 1268-1277.

Smith, D. W. 1995. Synchronous response of hydrophobic chemicals in Herring Gull eggs from the Great Lakes. Environmental Science and Technology 29: 740-750.

Additional Information

Additional information on Herring Gulls, monitoring programs on other fish-eating birds and wildlife in the Great Lakes may be obtained from the following address:

Environment Canada
Canadian Wildlife Service (Ontario Region)
P.O. Box 5050,
Burlington, Ontario L7R 4A6

Information on Great Lakes issues may be obtained from the following addresses:

Environment Canada 4905 Dufferin St. Downsview, Ontario M3H 5T4	or	The International Joint Commission 100 Ouellette Ave. Windsor, Ontario N9A 6T3

Additional fact sheets in this Great Lakes series:

- Bringing the Bald Eagle Back to Lake Erie
- The Fall and Rise of Osprey Populations in the Great Lakes Basin
- The Rise of the Double-crested Cormorant on the Great Lakes: Winning the War Against Contaminants
- Amphibians and Reptiles in Great Lakes Wetlands: Threats and Conservation

For further information on this and other Great Lakes programs, visit Environment Canada's Greenlane on the World Wide Web: http://www.cciw.ca/glimr/intro.html

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